Mud volcanoes – Analogs to martian cones and domes (by the thousands !)

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Mud volcanoes are mounds formed by low temperature slurries of gas, liquid, sediments and rock that erupt to the surface from depths of meters to kilometers. They are common on Earth, with estimates of thousands onshore and tens of thousands offshore. Mud volcanoes occur in basins with rapidly-deposited accumulations of fine-grained sediments. Such settings are ideal for concentration and preservation of organic materials, and mud volcanoes typically occur in sedimentary basins that are rich in organic biosignatures.

Domes and cones, cited as possible mud volcanoes by previous authors, are common on the northern plains of Mars. Our analysis of selected regions in southern Acidalia Planitia has revealed over 18,000 such features, and we estimate that more than 40,000 occur across the area. These domes and cones strongly resemble terrestrial mud volcanoes in size, shape, morphology, associated flow structures and geologic setting. Geologic and mineralogic arguments rule out alternative formation mechanisms involving lava, ice and impacts.

We are studying terrestrial mud volcanoes from onshore and submarine locations. The largest concentration of onshore features is in Azerbaijan, near the western edge of the Caspian Sea. These features are typically hundreds of meters to several kilometers in diameter, and tens to hundreds of meters in height. Satellite images show spatial densities of 20 to 40 eruptive centers per 1000 km^2. Many of the features remain active, and fresh mud flows as long as several kilometers are common.

A large field of submarine mud volcanoes is located in the Gulf of Cadiz, off the Atlantic coasts of Morocco and Spain. High-resolution sonar bathymetry reveals numerous km-scale mud volcanoes, hundreds of meters in height. Seismic profiles demonstrate that the mud erupts from depths of several hundred meters. These submarine mud volcanoes are the closest morphologic analogs yet found to the features in Acidalia Planitia.

We are also conducting laboratory analyses of surface samples collected from mud volcanoes in Azerbaijan, Taiwan and Japan. X-ray diffraction, visible / near infrared reflectance spectroscopy and Raman spectroscopy show that the samples are dominated by mixed-layer smectite clays, along with quartz, calcite and pyrite. Thin section analysis by optical and scanning electron microscopy confirms the mineral identifications. These samples also contain chemical and morphological biosignatures, including common microfossils, with evidence of partial replacement by pyrite. The bulk samples contain approximately 1 wt% total organic carbon and 0.4 mg / gm volatile hydrocarbons.

The thousands of features in Acidalia Planitia cited as analogous to terrestrial mud volcanoes clearly represent an important element in the sedimentary record of Mars. Their location, in the distal depocenter for massive Hesperian-age floods, suggests that they contain fine-grained sediments from a large catchment area in the martian highlands. We have proposed these features as a new class of exploration target that can provide access to minimally-altered material from significant depth. By analogy to terrestrial mud volcanoes, these features may also be excellent sites for the sampling martian organics and subsurface microbial life, if such exist or ever existed.